Research Square

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High Prevalence of Labral Inversion in Residual Hip Dysplasia Following Nonoperative Treatment in Infancy

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Research Article

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Abstract

Purpose

Developmental dysplasia of the hip (DDH) predisposes patients to secondary hip osteoarthritis and early total hip arthroplasty. Although non-surgical management is standard for infantile DDH, residual hip dysplasia (RHD) commonly develops and necessitates subsequent periacetabular osteotomy (PAO). However, few studies have focused on bony and labral morphological differences between treated and treatment-naive DDH patients. This study aimed to compare hip morphological parameters and labral inversion prevalence between these two cohorts to clarify the morphological characteristics of post-treatment RHD.

Methods

A retrospective analysis was performed on patients who underwent PAO between January 2014 and December 2024 and had infantile non-surgical DDH treatment (Pavlik harness, closed reduction, casting, or abduction bracing). Patients with prior hip/pelvic surgery or neuromuscular disorders were excluded. Preoperative imaging parameters and Magnetic Resonance Imaging(MRI) labral morphology were recorded. The control group included untreated DDH patients undergoing hip preservation surgery, matched 1:2 by LCEA, age, and treatment period. T-tests, non-parametric tests, and univariate regression were used for analysis.

Results

The prior non-operative treatment group included 45 patients (52 hips), and the control group included 98 patients (104 hips). The incidence of labral inversion was significantly higher in the treatment group (27 hips, 51.92%) compared to the control group (18 hips, 17.31%) ($P < 0.001$). The FA was significantly larger in the treatment group (45.73°±13.74°) than in the control group (32.28°±15.48°) ($P < 0.001$). Subgroup analysis based on the timing of initial treatment revealed that patients who received initial intervention after 18 months of age (older subgroup) exhibited a significantly larger TA compared to those treated before 18 months of age (younger subgroup) ($P = 0.031$).

Conclusions

Prior nonoperative treatment in infancy is associated with a significantly higher prevalence of labral inversion and greater femoral anteversion in patients requiring PAO for RHD. Later initial treatment and more severe initial dislocation correlate with poorer acetabular development.

Introduction

Developmental dysplasia of the hip (DDH) is a common hip deformity characterized by femoral head-acetabulum mismatch, which increases hip joint stress and often leads to severe secondary osteoarthritis, with nearly half of patients requiring total hip arthroplasty before 50 years of age [1].

DDH treatment depends on age and severity. Since acetabular intrinsic corrective potential declines significantly after 3–4 years of age [2], non-surgical interventions (Pavlik harness, closed reduction with casting/bracing) are the mainstay for children under 3 years; open reduction is needed if closed reduction fails to achieve stable femoral head-acetabulum congruence. With increasing age and waning acetabular corrective capacity, non-surgical management becomes insufficient, and corrective pelvic osteotomies are often required for older children [2, 3]. Although these treatments generally achieve stable concentric hip reduction, long-term follow-up shows a high incidence of residual hip dysplasia (RHD) due to incomplete acetabular remodeling during growth [4-6], with 35–58% of cases requiring reoperation for RHD—closed reduction is associated with higher reoperation rates than open reduction [7-10].

Periacetabular osteotomy (PAO) is an effective hip-preserving procedure for symptomatic DDH, as it mobilizes and reorients the acetabular fragment to enhance hip weight-bearing area and slow osteoarthritis progression [11, 12]. PAO significantly improves clinical symptoms regardless of prior DDH treatment [13], but PAO for RHD is technically more challenging and associated with higher complication rates (undercorrection, posterior column fracture, osteotomy nonunion, osteoarthritis progression) compared with PAO for treatment-naive DDH [14, 15].

While previous studies have compared bony morphology in RHD, there is a paucity of data focusing on the associated soft-tissue pathology, specifically the labrum. Based on our long-term clinical observations, patients with RHD not only present with significant bony deformities but also exhibit a markedly higher prevalence of intra-articular pathologies, such as labral hypertrophy and inversion. . Therefore, this study aims to utilize radiographic evaluations to compare hip morphological differences between RHD patients with a history of non-operative treatment and DDH patients without any prior treatment, all of whom have undergone PAO. We hypothesize that RHD patients have more severe bony deformities and a higher prevalence of inverted labral.

Materials and Methods

General Data and Grouping

A retrospective analysis included 1078 DDH patients (1318 hips) who underwent PAO or combined PAO with proximal femoral osteotomy(PFO) at our institution (from January 2014 to December 2024).After exclusion (52 patients/56 hips with prior pelvic/hip surgeries; 1 patient/2 hips with neuromuscular disorders; 8 patients/8 hips with non-operative treatment initiated after 3 years or unclear timing; 1 patient/1 hip with incomplete imaging), 45 patients (52 hips) formed the treatment group (prior non-operative treatment, including adductor tenotomy). A control group (98 patients/104 hips) was selected at 1:2 ratio, matched by age (within 2 years difference), surgery year, and LCEA classification (Class

A:18°–25°; B:0°–18°; C:<0°)(Figure 1), from 971 patients (1199 isolated PAOs) without prior hip treatment(Figure 1).

This study was approved by the Institutional Review Board (IRB) of the Department of Orthopedics, the Fourth Medical Center of Chinese PLA General Hospital (approval No.: 2023KY002-KS001;Clinical trial number:not applicable.),and conducted in accordance with the Declaration of Helsinki and China's Personal Information Protection Law. Informed consent was obtained from all participants (or the legal guardians of minor participants aged <18 years with developmental dysplasia of the hip) prior to enrollment. Written informed consent forms were signed by all participants (or their legal guardians) and archived in the hospital's research data management system.All consent procedures were reviewed and approved by the aforementioned IRB to ensure ethical and legal compliance.

Imaging Measurements

The assessed preoperative imaging parameters included the femoral neck-shaft angle (FNSA), femoral anteversion angle (FA), Tönnis angle (TA), lateral center-edge angle (LCEA), anterior center-edge angle (ACEA), and the morphology of the labrum on Magnetic Resonance Imaging(MRI) of the affected hip.

The FNSA was measured on supine anteroposterior radiographs (30°abduction, 15°internal rotation). This positioning helps mitigate overestimation of the FNSA due to excessive femoral anteversion. The angle was defined as the intersection between the longitudinal axis of the femoral neck and the longitudinal axis of the femoral shaft (denoted as ∠1 in Figure 2).

Both LCEA and TA were measured on a standing anteroposterior pelvic radiograph. For LCEA, a vertical line (V-line) was drawn upward from the femoral head center, perpendicular to the horizontal reference plane, and a second line (A-line) from the femoral head center to the most lateral edge of the acetabular sourcil; the angle between these two lines (∠2 in Figure 2) is the LCEA. For TA, the angle was formed between a horizontal line parallel to the inter-teardrop line and a line connecting the medial and lateral edges of the acetabular sourcil (∠3 in Figure 2), with a higher TA indicating more severe acetabular dysplasia.

The ACEA was measured on a false-profile view radiograph obtained with the patient in a standing position. The pelvis was rotated approximately 65°relative to the detector, positioning the two femoral heads approximately 1 to 1.5 femoral head diameters apart. A vertical line (V'line) was drawn upward from the center of the femoral head, perpendicular to the horizontal plane. A second line (B line) was drawn from the center of the femoral head to the most anterior edge of the acetabular sourcil. The angle between these two lines represents the ACEA(denoted as ∠4 in Figure 3).

The FA was measured using Computed Tomography(CT) scans of the hip and knee joints acquired in the same patient position. On the affected hip CT, the axial slice with the largest cross-sectional area of the femoral neck was selected. The angle between the longitudinal axis of the femoral neck and the horizontal plane was measured as angle α. On the affected knee CT, the axial slice with the largest cross-

sectional area of the femoral condyles was identified. The angle between the line connecting the medial and lateral femoral condyles and the horizontal plane was measured as angle β. If the directions of α and β were consistent, the FA was calculated as α + β; if the directions were opposite, the FA was defined as |α - β|(Figure 4).

On hip MRI, the normal labrum in Figure 5a–c appears as a triangular, homogeneous low-signal structure with sharp margins and tight attachment to the acetabular rim. By contrast, the inverted labrum in Figure 5d–e is abnormally hypertrophic (2–3 times the thickness of a normal labrum), with its tip curled into the joint space and forming an angle with the acetabular cartilage. Figures 5f–h show the corresponding intraoperative findings, with the inverted labrum indicated by white arrows in Figure 5f-g.

Statistical Analysis

All data were recorded in Excel 2016 and analyzed via SPSS 25.0. Normality was tested by Kolmogorov-Smirnov/Shapiro-Wilk tests; continuous variables were compared via t-tests (normal) or Mann-Whitney U test (non-normal); categorical variables via chi-square/Fisher's exact test. Univariate logistic regression identified labral inversion-related factors. $P<0.05$ was statistically significant

Results

The treatment group included 28 hips classified as LCEA class B and 24 as class C (no class A hips), while the matched control group (1:2 ratio by LCEA classification) consisted of 56 class B and 48 class C hips. Baseline characteristics (gender, age, BMI, surgical side, surgical approach) were comparable between the two groups.

Comparative analysis of imaging parameters, univariate regression, and subgroup analysis by LCEA classification (Table 1) showed that the treatment group had significantly larger FNSA (139.46° ±9.12°compared with 134.71°±6.98°, P=0.001) and FA (45.73°±13.74°compared with 32.28°±15.48°, P<0.001), as well as a higher incidence of labral inversion (51.92% compared with 17.31%, P=0.003) than the control group; no significant differences were found in TA, LCEA, or ACEA (P>0.05). Univariate regression indicated that a history of non-operative treatment was a risk factor for labral inversion (OR=5.160, 95% CI=2.451–10.862, P<0.001).

Subgroup analysis by LCEA category showed that in Class B DDH (LCEA: 0–18°), the treatment group had significantly larger FNSA (139.85°± 9.01°compared with 133.80°±7.70°, P=0.002) and FA (45.30° ± 16.69°compared with 33.66°±15.49°, P=0.002), and a higher incidence of labral inversion (53.57% compared with 21.43%, P=0.006); in Class C DDH (LCEA < 0°), the treatment group had significantly larger FA (46.23°± 9.53°compared with 30.66°± 15.47°, P<0.001) and TA (32.68°± 8.40°compared with 28.73°± 6.04°, P=0.030), and a higher incidence of labral inversion (50.00% compared with 12.50%, P=0.003); no significant differences in other parameters were observed in either subgroup (P>0.05).

Table 1. Baseline characteristics, comparative analysis of imaging parameters, univariate regression analysis for labral inversion, and subgroup analysis of hip morphology by LCEA class (Class B and Class C) between the treatment and control groups.

a. Baseline characteristics between the treatment and control groups.

		Treatment group （n=52）	Control group （n=104）	t（Z）	P
Gender	Male	5	4	-0.731	0.470
	Female	47	100		
Age in years		22.79±7.15	24.92±5.64	0.062	0.100
BMI (kg/m²)		21.62±3.98	21.87±3.19	0.425	0.672
Surgical Side	Left	29	58	-0.390	0.700
	Right	23	46		
Type of surgery	PAO+PFO	32	54	-1.890	0.060
	PAO	20	50		

b. Comparative analysis of imaging parameters between the treatment group (with prior non-operative treatment) and the control group

	Treatment group（n=52）	Control group （n=104）	t	P
FNSA（°）	139.46±9.12	134.71±6.98	-3.605	0.001
FA（°）	45.73±13.74	32.28±15.48	-5.307	＜0.001
TA（°）	26.56±9.18	24.57±7.34	-1.469	0.144
LCEA（°）	1.96±11.26	1.68±10.60	-0.155	0.877
ACEA（°）	1.10±16.08	4.25±12.56	1.237	0.220
Labral Inversion	27(51.92%)	18(17.31%)	-2.956	0.003

c. Univariate regression analysis of factors associated with labral inversion(OR = odds ratio;CI = confidence interval)

	χ^2-value	P -value	Odds Ratio (OR)	95%CI
Gender	0.326	0.568	1.449	(0.403,5.216)
LCEA	0.964	0.326	0.704	(0.348,1.421)
Surgical Side	0.029	0.865	0.941	(0.469,1.889)
With or without PFO	0.005	0.946	1.025	(0.510,2.057)
History of Non-operative Treatment	20.238	＜0.001	5.160	(2.451,10.862)

d. Comparative analysis of imaging parameters between Class B DDH patients (LCEA: 0–18°) in the two groups.				
	Treatment group（n=28）	Control group （n=56）	t（Z）	P
FNSA（°）	139.85±9.01	133.80±7.70	-3.202	0.002
FA（°）	45.30±16.69	33.66±15.49	-3.163	0.002
TA（°）	21.32±6.11	21.00±6.46	-0.214	0.831
LCEA（°）	10.70±4.42	10.19±3.64	-0.560	0.709
ACEA（°）	7.34±12.07	11.04±9.65	1.524	0.577
Labral Inversion	15（53.57%）	12（21.43%）	-3.106	0.006
e. Comparative analysis of imaging parameters between Class C DDH patients (LCEA < 0°) in the two groups				
	Treatment group（n=24）	Control group （n=48）	t（Z）	P
FNSA（°）	139.00±9.41	135.77±5.93	-1.536	0.130
FA（°）	46.23±9.53	30.66±15.47	-4.512	（0.001
TA（°）	32.68±8.40	28.73±6.04	-2.292	0.030
LCEA（°）	-8.23±7.53	-8.26±6.61	-0.014	0.990
ACEA（°）	-6.18±17.31	-3.68±10.83	0.751	0.455
Labral Inversion	12（50.00%）	6（12.50%）	-3.264	0.003

No statistically significant differences in FNSA, FA, TA, LCEA, or ACEA were found between patients with and without labral inversion (Table 2).

Table 2. Comparisons of imaging parameters between patients with and without labral inversion

	Without Labral Inversion （n=111）	With Labral Inversion （n=45）	t	P
FNSA（°）	136.32±8.17	136.22±7.81	0.071	0.944
FA（°）	35.26±16.81	40.47±14.01	-1.834	0.069
TA（°）	25.58±8.09	24.38±7.90	0.849	0.397
LCEA（°）	1.41±10.65	2.66±11.21	-0.658	0.511
ACEA（°）	3.03±13.00	3.61±15.94	-0.239	0.812

After excluding 1 hip due to uncertain initial treatment timing, 51 hips (44 patients) in the treatment group were stratified into younger (treatment initiated ≤18 months after birth, 24 hips) and older (18–36 months after birth, 27 hips) subgroups. The older subgroup had a significantly larger TA $P = 0.031$, while no significant differences were found in other parameters or the prevalence of labral inversion (P>0.05) (Table 3).

Table 3. Comparisons of imaging parameters and labral inversion prevalence between younger and older subgroups in the treatment group

	Younger group (n=24)	Older Group (n=23)	t/Z	P
FNSA (°)	137.7±9.57	140.90±8.75	-1.249	0.218
FA (°)	44.63±13.56	45.93±13.77	-0.338	0.737
TA (°)	23.91±7.62	29.37±9.68	-2.221	0.031
LCEA (°)	4.10±11.49	-0.37±10.81	1.429	0.159
ACEA (°)	5.53±16.14	-2.17±13.70	1.843	0.071
Labral Inversion	15 62.50%	12 44.44%	1.285	0.205

Discussion

Patients who previously underwent non-operative treatments such as closed reduction exhibit higher reoperation rates than those with a history of surgical interventions like open reduction, as confirmed in previous studies [9, 13-15]. The principal finding of this study is the markedly higher incidence of labral inversion (51.9% vs. 17.3%) in RHD patients with prior infantile nonoperative treatment compared to those without such a history. This observation, coupled with significantly increased femoral anteversion, delineates a distinct morphological profile in this patient subset. It is hypothesized that this may be related to more severe residual hip deformities in this population.

Current research on hip morphology in RHD patients remains limited. In a few recent reports, Bridget K et al. [16] suggested that RHD patients with a history of non-pelvic osteotomy treatments during infancy exhibit hip morphology similar to that of DDH patients without any prior treatment history. However, this finding does not fully explain why PAO for RHD is more complex and carries a higher risk of complications. Zhang Z et al. [15] reported that PAO significantly improves hip function and corrects morphological deformities in DDH patients regardless of previous treatment history, but noted that residual DDH demonstrates more severe morphological abnormalities than primary DDH without prior intervention. Similarly, LIU H-J et al. [17] finding that RHD patients had more severe deformities, including

greater femoral anteversion, higher femoral head extrusion index, and poorer posterior acetabular coverage. These findings are consistent with our results.

Labral Inversion

The labrum is a fibrocartilaginous structure that attaches circumferentially to the acetabular rim in a horseshoe-shaped manner. By deepening the acetabulum and increasing femoral head coverage, it significantly enhances joint stability [23]. R.M. Seldes et al. [24] demonstrated in a study of adult acetabular labra that the labrum contributes approximately 22% of the articular surface and increases acetabular volume by 33%. The pathological changes in DDH extend beyond bony abnormalities to include intra-articular soft tissues, cartilage, the joint capsule, and the labrum. Particularly in pediatric DDH, a hypertrophied labrum enveloped by fibrous tissue becomes a key obstacle to concentric reduction, significantly influencing treatment decisions and outcomes [25,26].

Internationally recognized classification systems for assessing the severity of pediatric DDH include the Tönnis classification and the International Hip Dysplasia Institute (IHDI) classification. Both systems note that as dislocation severity increases, labral morphology transitions primarily from everted to mixed or inverted [27]. Progressive labral inversion exacerbates narrowing at the acetabular entrance, becoming a critical factor in the failure of closed reduction [26,28].

The fate of the inverted labrum after closed reduction remains controversial. Earlier studies suggested that after stable closed reduction, interposed soft tissues, including the inverted labrum, would be gradually absorbed and remodeled, as inferred indirectly from hip arthrography and the “docking” phenomenon of the femoral head [29-31]. However, these hypotheses lacked direct evidence. In contrast, ZHOU W et al. [32], through dynamic MRI observation of hip joint space after closed reduction for DDH, found that although mildly widened joint spaces eventually achieved concentric reduction after fixation, the inverted labrum was not completely absorbed in 86.7% of cases within two years post-operation. Instead, it evolved into a thin fibrous layer interposed between the femoral head and acetabulum and did not resolve with subsequent growth and development [33,34].

In the present study, the incidence of labral inversion was significantly higher in the prior non-operative treatment group (27 hips, 51.92%) compared to the no-prior-treatment control group (18 hips, 17.31%) (P=0.003). This significant difference persisted across both class B and class LCEA severity subgroups, indicating that inverted labrum does not resolve with child growth and may persist as an important factor impairing acetabular development and contributing to RHD.

Nonoperative Treatment and RHD

For infants under six months of age with DDH, the Pavlik harness is a widely accepted and effective treatment. It maintains the hip in 30° to 60° of abduction to achieve reduction—abduction less than 30° may lead to persistent dislocation, while exceeding 60° increases the risk of avascular necrosis of the femoral head [2]. However, the success of this treatment partly depends on parental compliance and

correct application of the harness. A literature review on Pavlik harness treatment for DDH reported that 9.49% of successfully reduced hips showed radiographic evidence of RHD, with 4.14% requiring additional surgery [35]. Younger age at initial treatment, higher severity of dislocation, bilateral involvement, and labral inversion have been identified as risk factors for RHD following Pavlik harness treatment [2,36].

For children older than six months, closed reduction followed by spica casting or bracing is commonly employed, as the acetabulum retains potential for spontaneous development and remodeling after stable concentric reduction. However, as age increases, this regenerative capacity diminishes, leading to a higher incidence of RHD. The upper age limit for successful closed reduction remains controversial, as it is unclear when the acetabulum loses its ability to remodel post-reduction [2,3,37]. Literature reports indicate that approximately two-thirds of children under 18 months and 50% of those between 18 months and 3 years achieve stable reduction through closed reduction [38]. Although significant spontaneous improvement can occur even in patients over 18 months, rates of RHD and reoperation are higher in this group compared to younger patients. Persistent inverted labrum may impair acetabular cartilage development, contributing to the development of RHD [28].

In our study, when comparing patients based on LCEA classification, those with a history of non-operative treatment and classified as Grade C (LCEA < 0°) exhibited a significantly larger TA compared to the control group. This indicates that more severe dislocation is associated with poorer acetabular development in patients with prior treatment. Furthermore, the incidence of labral inversion was higher in this subgroup, supporting the hypothesis that residual inverted labrum may disrupt acetabular cartilage development and contribute to RHD. Univariate regression analysis confirmed that a history of non-operative treatment is a significant risk factor for labral inversion, consistent with previous studies.

This study demonstrates that patients with RHD who underwent non-operative treatment before age of 3 years exhibit distinct hip morphological characteristics compared to treatment-naive patients. Specifically, the prior treatment group showed a significantly higher prevalence of labral inversion and more severe proximal femoral deformity, characterized by increased FA.

Notably, while the prior treatment group overall demonstrated a larger FNSA, this difference was not maintained in the subgroup analysis of Grade C patients (P =0.130). To address potential measurement bias from excessive FA, all radiographic evaluations were performed in a standardized functional position (30° abduction and 15° internal rotation). However, given that most DDH patients exhibit FA values substantially exceeding 15°, complete elimination of measurement variability remains challenging.

Stratification by treatment timing (18-month cutoff) revealed significantly greater TA in the older subgroup (P=0.031). Although statistically non-significant, both LCEA and ACEA showed reduced values in older patients, indicating poorer acetabular development with delayed treatment, consistent with existing literature.While no other imaging parameters differed significantly between age subgroups, possibly due to recall bias in treatment history documentation.

Interestingly, comparative analysis between hips with and without labral inversion revealed no significant differences in standard radiographic parameters. This lack of correlation may be attributed to our limited sample size and the qualitative rather than quantitative assessment of labral inversion severity. Future studies incorporating advanced quantitative imaging techniques and larger cohorts may help elucidate subtle morphological patterns associated with labral pathology.

Limitations

First, the retrospective design introduces potential selection bias. To address this concern, we implemented a 1:2 matched cohort design based on age, LCEA classification, and surgical period to enhance comparability between groups.Age, LCEA classification, and surgical period-key confounding factors for hip disease prognosis—were effectively controlled via 1:2 matching, ensuring group baseline homogeneity. This supports that outcome differences are attributed to the intervention itself, not biases, and validates the conclusion's reliability.

Second, detailed historical treatment records were unavailable. Treatment history relied on recall by patients or their families, which may have led to misclassification, some patients in the control group might have undergone unrecognized early treatment, while inaccuracies in timing might have introduced bias. Nevertheless, we conducted thorough interviews to document prior treatments in electronic medical records, and significant interventions such as harness, cast, or brace use are generally well-remembered.Major interventions affecting hip development are highly memorable, and thorough interviews minimized misclassification of key information. Minor unrecorded treatments are unlikely to alter the intervention's superior efficacy trend, ensuring the conclusion's robustness.

Finally, labral inversion was assessed only qualitatively without quantitative grading. This limitation precludes evaluation of the extent to which the severity of inversion influences RHD or its evolution after different non-operative treatments. Future studies should incorporate standardized quantitative measurements to better understand the impact and natural history of labral pathology.Qualitative assessment of labral inversion (presence/absence) sufficiently supports its association with RHD, the study's core objective. The lack of quantitative data does not negate this association but reminds readers the conclusion applies to inversion presence, not severity.

Conclusion

In conclusion, RHD patients with a history of nonoperative treatment in infancy present for PAO with a distinct morphological phenotype, prominently featuring a high rate of labral inversion and increased femoral anteversion. Furthermore, later initiation of treatment and more severe initial dislocation are associated with poorer acetabular development in patients with RHD. These findings indicate that early intervention does not guarantee normalization of hip architecture and may be associated with persistent soft-tissue pathology. This underscores the importance of recognizing labral inversion as a key feature in the planning of hip-preserving surgery for RHD and suggests that infants undergoing nonoperative treatment warrant long-term surveillance not just for bony dysplasia, but also for soft-tissue sequelae.

Abbreviations

Abbreviation	Full name
DDH	Developmental Dysplasia of the Hip
RHD	Residual Hip Dysplasia
PAO	periacetabular osteotomy
MRI	Magnetic Resonance Imaging
LCEA	Lateral Center-Edge Angle
FNSA	Femoral Neck-shaft Angle
FA	Femoral Anteversion Angle
TA	Tönnis angle
ACEA	anterior center-edge angle
CT	Computed Tomography
SPSS	Statistical Package for the Social Sciences
IBM	International Business Machines Corporation
OR	Odds Ratio
CI	Confidence Interval

Declarations

Author Contribution

All authors contributed to the study conception and design.HF,ZG,JZ: Conceptualization, Data curation (collected and verified data of DDH patients), Formal analysis (performed logistic regression),Writing - original draft.WC,ZC: Methodology (established the diagnostic criteria for residual acetabular dysplasia), Supervision,Writing - review & editing.ZZ,DL,HZ: Conceptualization, Funding acquisition, Supervision, Writing - review & editing (final version), responsible for the integrity of the data.All authors read and approved the final manuscript.

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Human Ethics and Consent to Participate

This study was approved by the Institutional Review Board of the Fourth Medical Center of PLA General Hospital (approval number: 2023KY002-KS001). All procedures were performed in accordance with the ethical standards of the institutional research committee, the Declaration of Helsinki, and China's Personal Information Protection Law. Informed consent was obtained from all participants or their legal guardians for minor patients. All participants were fully informed of the study purpose, procedures, potential risks, benefits, and the right to withdraw. Written informed consent was signed by each participant or legal guardian. No participant was enrolled without valid informed consent.

Consent to publish

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments.The author affirm that human research participants provide informed consent for publication of the images in Figure5f,5g and 5h.

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Figures

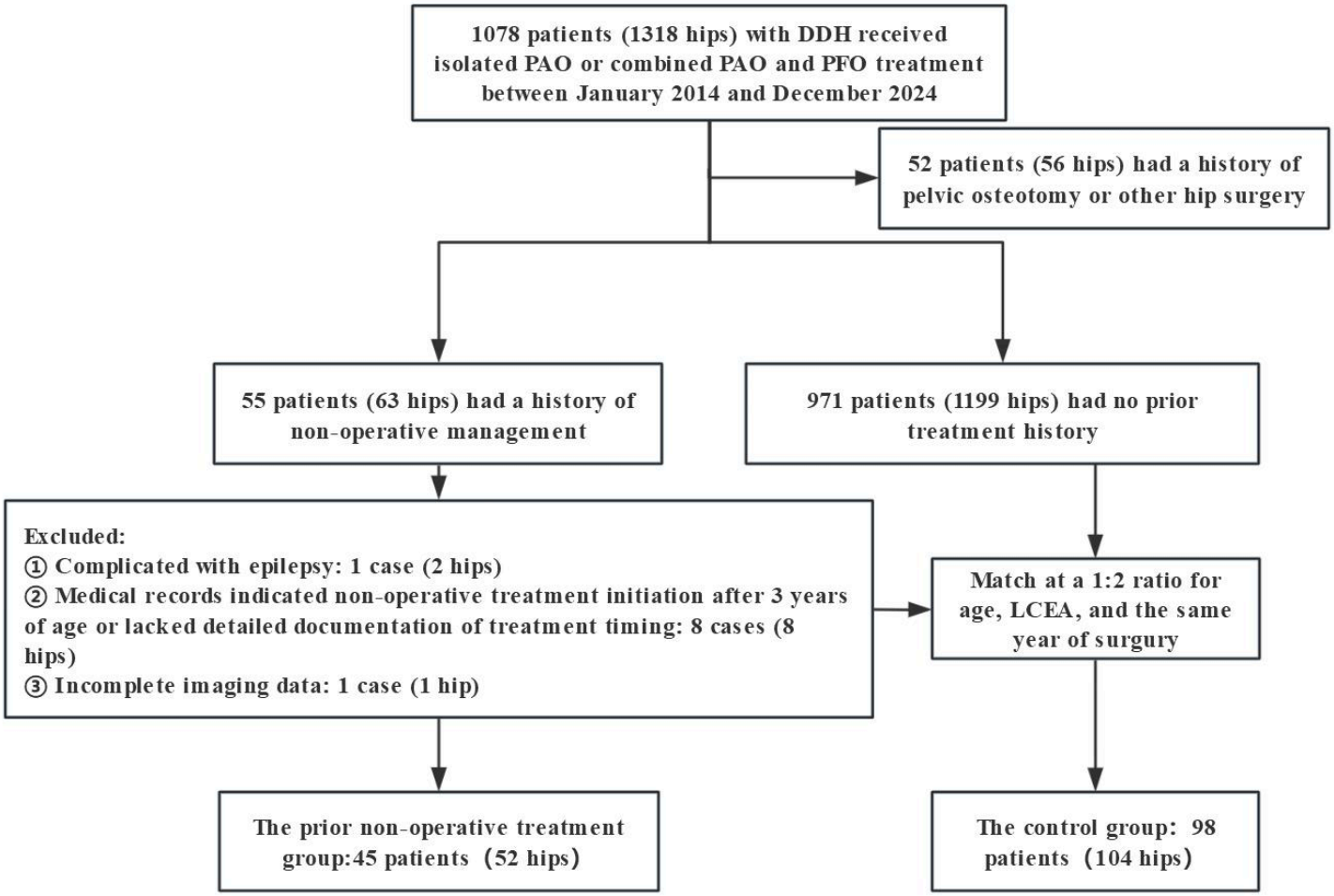


Figure 1

Flow chart of study population selection

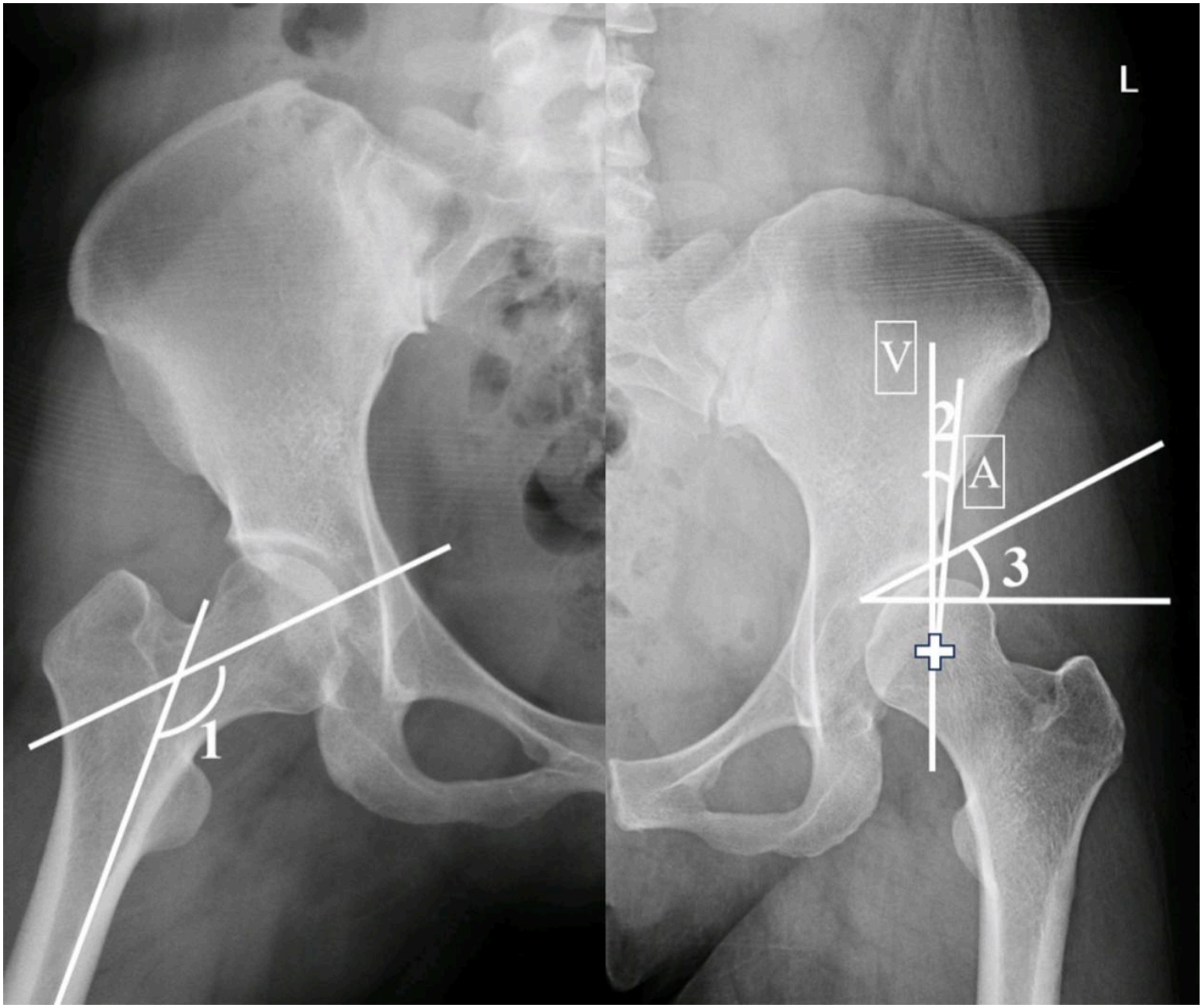


Figure 2

Measurement of the FNSA, LCEA, and TA..

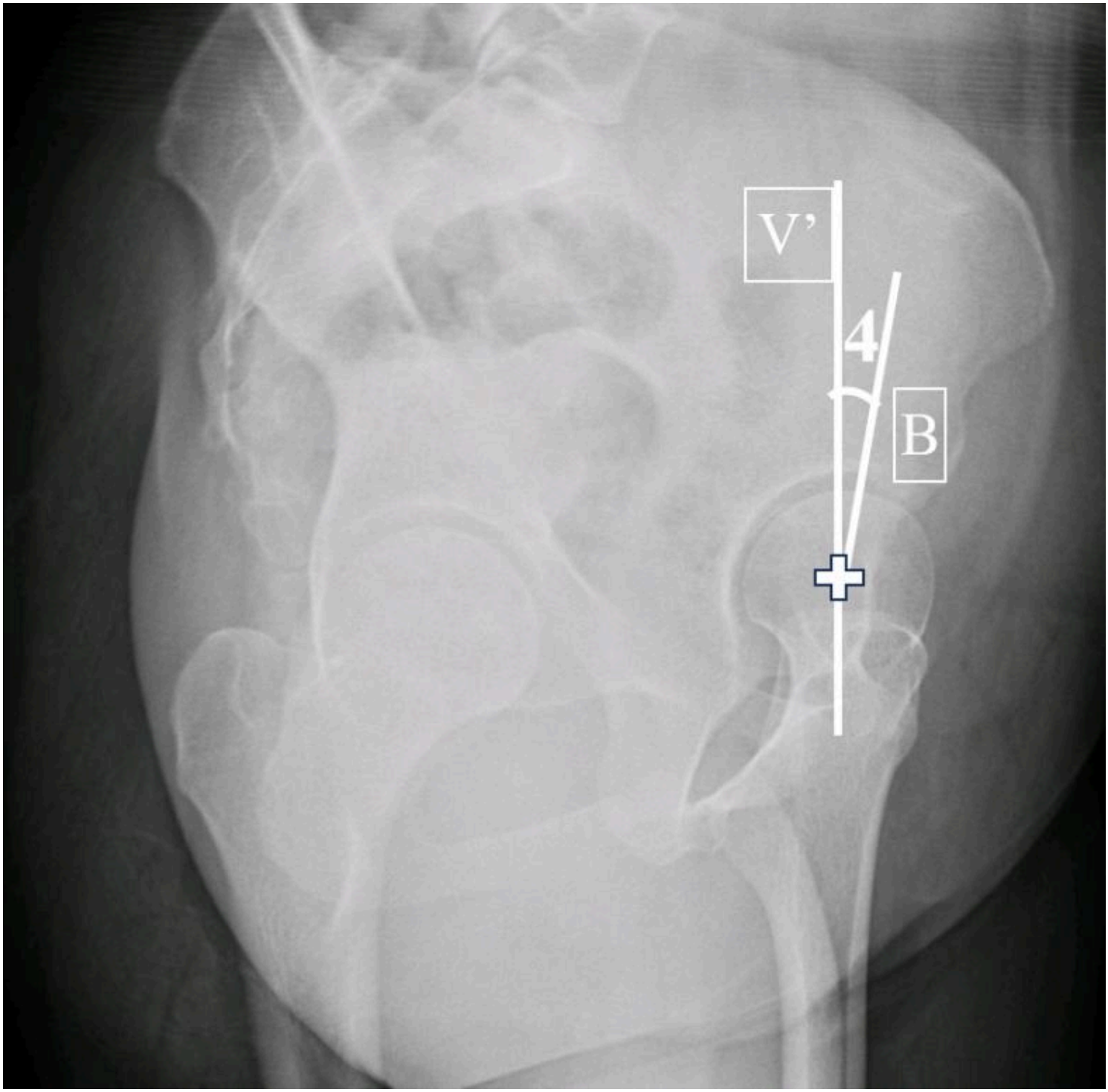


Figure 3

This figure depicts the measurement of the ACEA.

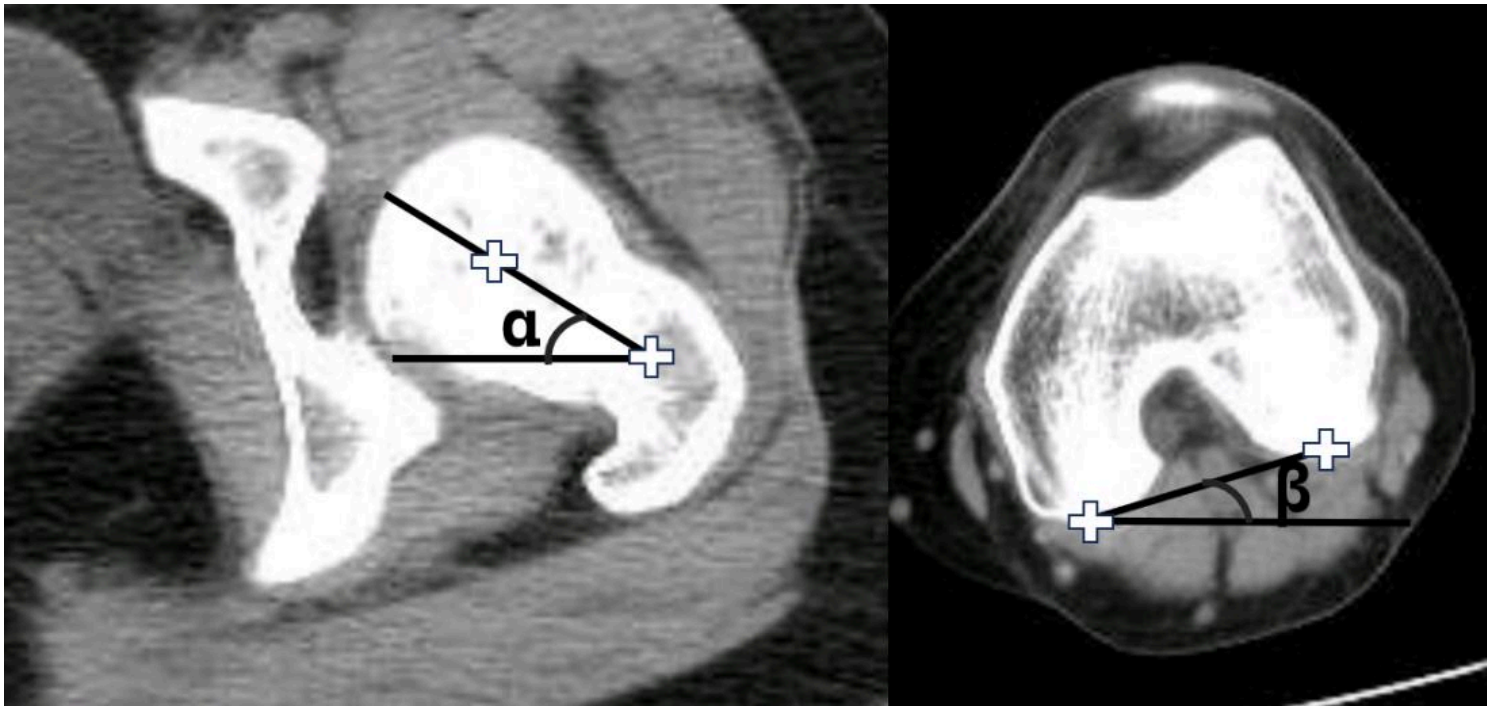


Figure 4

This figure depicts the measurement of the FA.

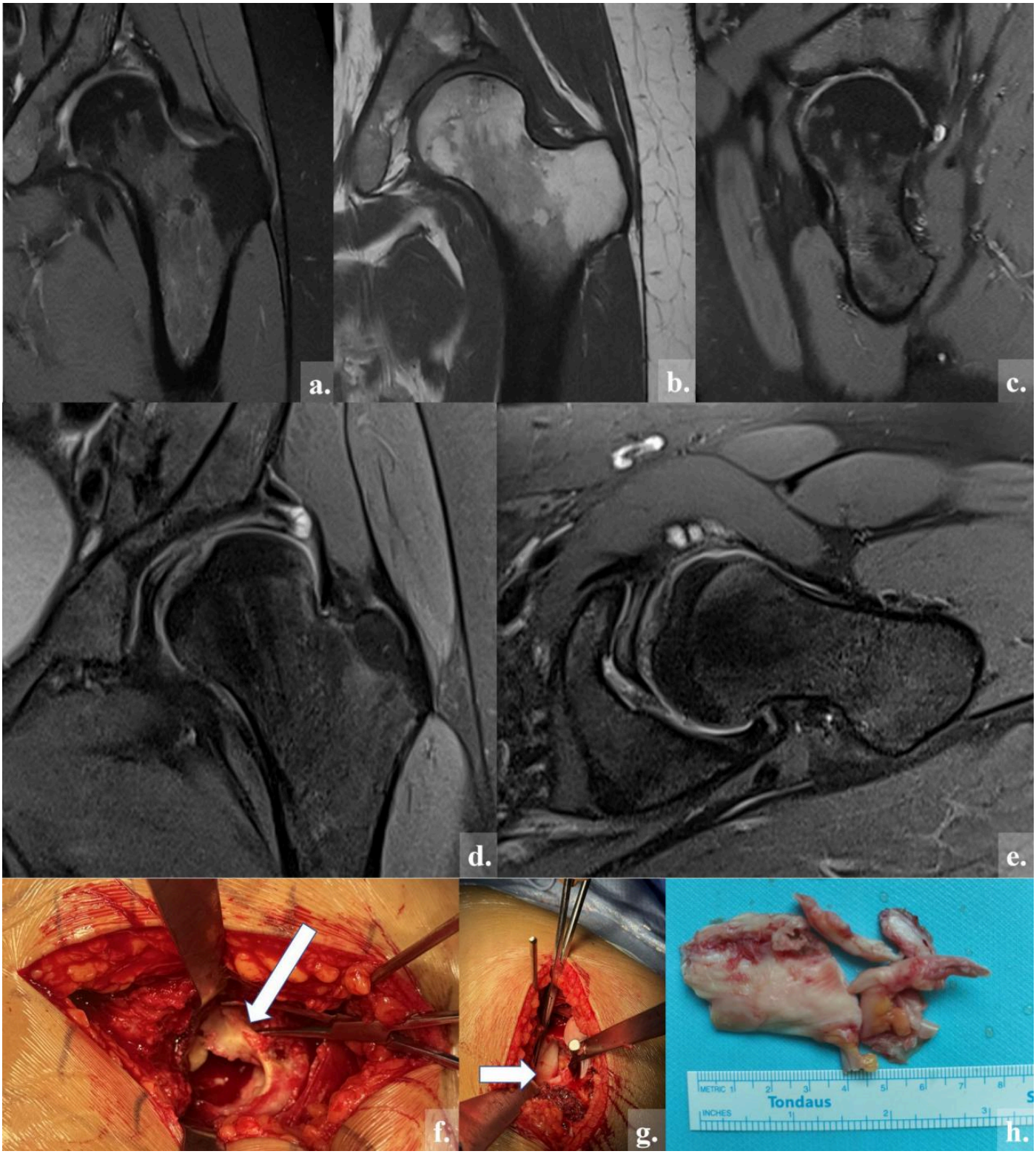


Figure 5

This figure illustrates the evaluation of labral morphology on MRI of the affected hip.